APPLIED MATHEMATICS AND STATISTICS LABORATORIES

STANFORD UNIVERSITY
CALIFORNIA

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W. G. IRESON

TECHNICAL REPORT NO. 43

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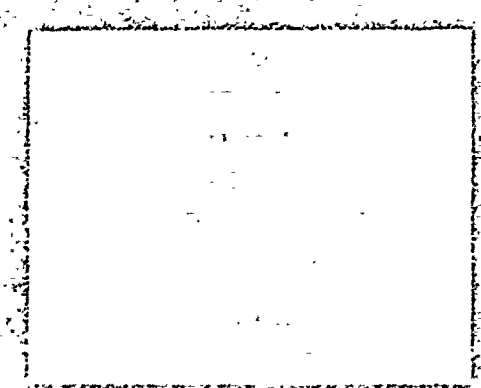

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0. Preface.

Although the IRAN program is solely an Air Force program, in some ways it can be compared to almost any manufacturing operation, and the three usual elements, incoming inspection, in-process control, and quality assurance audit, can be applied quite readily. Hence, it was felt that this report would be of benefit to personnel of all of the services.

I. Introduction.

The introduction of the IRAN program (Inspect and Repair as Necessary) by the Air Force produced some new problems in the Maintenance Quality Control Program and intensified some existing ones.

Prior to the IRAN program, aircraft were returned to the prime Air Matériel Area (AMA), where the aircraft was stripped down to its skeleton and essentially rebuilt into a new or "as new" airplane. While all incoming aircraft were in widely ranging conditions, by the time they had been stripped, the work to be done was essentially constant. Except for the slight differences in the amount of work that needed to be done on accessories, the total amount of work and the quality of workmanship was the same on all planes.

Even during that period the use of statistical quality control techniques was limited. It is only fair to say that the maintenance

qual.ty control activities were lagging behind procurement quality control in the use of sampling plans, in-process control, and quality audits.

The IRAN concept meant a major change in maintenance procedures. When an AMA was indicated as "prime" relative to a new aircraft, it very shortly "prototyped" the plane. That is, one airplane was brought in and completely analyzed so that all possible maintenance and overhaul tasks were identified and a "work book" was prepared. The work book contained a description of every maintenance and overhaul job. Work orders were printed corresponding to the tasks in the work book.

When an airplane was brought in, for IRAN, it was, after proper preparation, inspected quite completely, and preprinted work order cards were attached to the plane for all work to be accomplished. Then each order was performed. If additional repairs were indicated as the plane progressed through the shop, additional work orders were issued.

Throughout the repair operation the line inspectors examined the work performed to see that all the required work was completed and that the quality of the workmanship was satisfactory.

As the plane progressed through the disassembly area various accessories, such as radio and navigation equipment, starters, generators, sheet metal parts, etc., were removed and sent to specialty shops for repair. In some cases the same part had to be returned to the same plane, while in others it was just necessary to supply a similar item. Thus, some of the specialty shops had to schedule repair work according

to the schedule on the plane, while others could carry a supply of repaired parts and accumulate a "lot" of similar items before beginning maintenance work on them.

The objective of IRAN is not to turn out an "as new" plane, but one that is adequate in every respect to perform its mission until the next scheduled IRAN on it. Obviously the work load varied from plane to plane. The same work was not performed on all planes.

This brief summary of the changes introduced by the IRAN program serves to introduce the problems of quality control under that program.

The Quality Control Program.

It was stated earlier that line inspectors checked each work order to see that all work was performed satisfactorily. This introduced the first major problem. The number of line inspectors is quite limited and it is problematical whether the most conscientious inspector can really inspect thoroughly all the work in his area. Furthermore, the inspector usually becomes quite friendly with the workmen and may be inclined to tell the workman about his mistakes or omissions, rather than make the usual report. Also, the work may become rather routine, so that the inspector may tend to ignore or overlook some of the requirements. Confidence in his friends who do the work may influence him to omit inspections or perform them only superficially.

Various attempts to avoid these difficulties have had various degrees of success. Rotating inspectors may reduce their individual effectiveness

because they are frequently forced to work in a new and unfamiliar specialty. Thorough supervision is another possible solution but again manpower problems arise. Maintaining an audit of the inspection seems to be the most practical solution.

Before certain areas of the airplane are closed up and again at the end of the line, final inspections are performed. The airplane is divided up into a number of areas, 9 to 15, depending upon the type, and a certain number of areas are inspected on each airplane. Thus, by the time 5 to 10 airplanes have been passed, every area will have had two to three inspections. This is a sampling plan, but the areas to be inspected are not necessarily chosen at random. Past experience is likely to be the basis for choosing the areas to be inspected, and it is possible for the same areas to be omitted for a number of planes.

Quality control in the specialty shops is operated in somewhat the same way, except that each workman is supposed to inspect his own work. That is, somewhat more emphasis is placed on the individual workman's responsibility. The output of the specialty shops may be sampled or 100% inspected by the department inspectors.

The quality control techniques to be employed are left almost entirely to the quality control representative at each AMA. He may employ any or all of the techniques described in the various AMC manuals. He may also devise any methods he likes relative to the reporting of quality control data from the various divisions of the maintenance activity.

II. Objections to Statistical Quality Control Techniques.

This memorandum was instigated by the fact that many quality control personnel in the maintenance program have objected to the use of the usual statistical quality control techniques in the IRAN program. On the other hand, it must be reported that two AMA's visited were making extensive use of statistical techniques in some parts of the IRAN program. The objections to the use of statistical techniques were similar to the objections raised by inspectors and others when statistical quality control was introduced to industry. They are:

(A) The incoming material (airplanes and parts) are all in different conditions. Therefore, we cannot assume a stable universe.

(B) The numbers are so small that we cannot apply sampling techniques.

(C) The product is so critical that we cannot take a chance on turning out a defective airplane.

(D) The work load is not uniform and the inspector must be shifted around on various jobs.

The premise on which these conclusions are based are, in general, true, but the conclusions are not necessarily valid. The fact that the incoming material is not constant, or all in the same condition, is almost irrelevant, because the objective is to set up and control a process that will assume the outgoing material (planes and parts) will be of a constant quality. This means that it is the purpose of quality control to see that the men,

equipment, and facilities are used in such a way that the defective parts or defects in the aircraft are identified and repaired. With hundreds of opportunities for a defect to occur in any number of accessories or systems in the aircraft, it is perfectly obvious that sampling can be applied to evaluate the effectiveness of the total process by which defects, defectives, or discrepancies are identified and corrected.

The number of items to be repaired is much less important than the number of opportunities for defects to be passed. The concept of defects per unit can be applied to radios, hydraulic systems, or nay other systems even if such systems are only turned out infrequently, say once a week. The idea is clearly to control the process, consisting of the workmen, equipment, and facilities, to assure that the outgoing product is consistently acceptable.

Certainly any characteristics that are critical should not be sampled. The procedures specified in practically all the quality control manuals require that all critical defects be inspected 100%. There are, however, many characteristics of major or minor classification that can be controlled by sampling. The fact that so many unsatisfactory reports (U.R.'s) arrive on each aircraft indicates that the defects are not being detected by the present system of quality control. The use of sampling plans would at least provide an indication of the risk that is being taken, and would permit evaluation of the process at the time when the defects were occurring, rather than weeks or months later from U.R.'s.

The non-uniformity of the work load can be accomodated more easily through the use of sampling plans than without them. It seems to be apparent from visits to AMA maintenance facilities that there are not enough inspectors to provide really 100% inspection of all the work. This results in an unplanned (and sometimes ineffectual) sampling procedure that can lead to inaccurate reports and undue stress on certain details to the neglect of others. A formal, randomized sampling plan assumes that all areas will be given a fair amount of inspection, and permits more thorough inspection of a smaller number of characteristics. The assurance will be better and the variable work load can be handled more easily with formal sampling.

Another fact should be kept clearly in mind. Maintenance quality control has the responsibility of furnishing information to the top management of the AMA on which major decisions will be made. Inaccurate or incomplete information will tend to cause poor decisions to be made. Allocation of funds for manpower, matériel, and contract expenditures is only one of the major decisions to be made, and it is affected by quality control's reports on such matters as defects or demerits per 100 earned man hours, number of defects or demerits per aircraft at final inspection, etc. Only by controlling the quality control activities so that the reports from month to month have a consistent validity can top management be expected to make consistently good decisions. The employment of sound statistical sampling plans and valid analyses can help the quality control group fulfill this requirement.

III. Opportunities for Statistical Quality Control Techniques in the IRAN Program.

There are many opportunities to make valuable use of statistical quality control techniques in the IRAN program. Some specific suggestions are given here. An open-minded evaluation of the specific conditions and problems in the different AMA's undoubtedly will indicate many others.

The largest single area, and the most obvious, is in the control of the quality of workmanship performed by inspectors, mechanics, clerks, and others associated with the IRAN program. It is said that the X and R charts indicate the level of quality (dimensional), the basic variability of the process, and the consistency of quality from day to day or hour to hour. These statements, of course, refer to control of product quality. They can just as easily refer to workmanship, measured in terms of the number of defects created or missed by the workman per hour, day, or week. Perhaps it must be measured for a team or crew of workmen, but it is still a measure of the workmen's ability to detect and correct defective conditions, consistency of their performances, and a measure of the outgoing quality.

This concept can be applied to the inspectors who make the intial inspection and specify the work to be performed, as well as to the mechanics or line inspectors. In both AMA's visited and in at least one contractor's plant, it was stated that the initial inspection was not good enough to give a realistic work load estimate, and that schedules

prepared on the basis of the initial inspection were usually too optimistic. What better way could the effectiveness of the initial inspection be measured than in terms of the number of tasks performed that were missed on the initial inspection?

In some ways the IRAN program can be compared to almost any manufacturing operation, and the three usual elements, incoming inspection, in-process control, and quality assurance audit, can be applied quite readily. Materials, parts, and supplies, as well as aircraft and equipment for repair, are received. These come from many different organizations, both military and civilian. Certainly incoming inspection can be performed on a sampling basis on many of these items and the information put to good use in correcting the causes of defective materials or equipment. Does one wing or group provide worse on-line maintenance on its airplanes than others? Are one wing's planes consistently in worse condition than others? Are repair or spare parts from one depot consistently mislabeled, poorly packaged, or improperly repaired? Does one carrier cause more damage in transit than others? There are dozens of questions such as these that could be answered if the information from samples was analyzed statistically to identify "out of control conditions."

In-process control offers many opportunities for use of statistical techniques, as has previously been illustrated. Probably the most important is workmanship. It should be stressed, however, that little in the way of concrete value can be shown in there is only one point on a control chart per month. It is imperative that sampling be frequent enough to give a

quick indication of a shift in quality of workmanship. The results should be available immediately and should be used to call supervisory attention to problem areas while the problem is still present, rather than waiting for weeks or months. Corrective action can be far more effective at the time the problem is identified.

It is assumed that the in-process control will be based on information obtained by the line inspectors. How good is their workmanship, and how effective is the corrective action? The quality assurance audit should provide the answers to these questions. Certainly the final inspection before flight test cannot possibly be sufficient to check every quality characteristic in an airplane, but sampling (as was discussed earlier) by "areas" of the plane can provide a valid evaluation of the effectiveness of line workmanship and inspection.

Finally, statistical techniques should be employed in the analysis of U.R.'s to correlate the "squawks" received from the field with the quality indications obtained in-process and at final inspection.

All of these concepts are for the purpose of identifying as early as possible the causes of defectiveness, so that proper steps can be taken to prevent reoccurrence of those types of defects. The whole philosophy of statistical quality control is that prevention is more important than after-the-fact sorting of good from bad. This should be the objective of using statistical techniques, sampling plans, and control charts in the IRAN program.

Detailed samples could be cited from disassembly, repair, and assembly on aircraft systems, engines, and so forth. Similarly, samples are readily available from steps in the final release to flight line, flight line check, flight test, and post-flight test inspections and rework.

IV. Are New Statistical Techniques and Sampling Plans Needed?

The Department of Defense and the various branches of the Service have developed extensive statistical techniques and sampling plans. There are a great number of different types of plans dealing with variables and attributes, lot-by-lot or continuous, and single, double, and sequential procedures. In questioning representatives of both AMA's and contractors, no one suggested that new sampling plans were needed for the IRAN program.

It was generally suggested that effort to simplify the instructions and provide step-by-step procedures might help to gain more rapid acceptance by both workmen and inspectors. This really means that the supervisors of each IRAN program should devote more time to analysis of their peculiar problems and in preparation of standard procedures and instructions. Outsiders probably cannot do this as well as the local quality control representatives.

V. Why Aren't Statistical Quality Control Techniques in General Use in the IRAN Program?

An investigation into the real reasons why statistical quality control techniques are not in more general use in the IRAN program failed to provide

very much concrete evidence. These conclusions are based more on personal evaluation of replies to questions than to the actual replies.

There is one major restriction that can be documented. Technical Orders require that certain items be inspected at specified intervals and declared usable, reparable, or scrap. There is no provision for sampling in the technical order, and even if the items are small and numerous, they are treated individually through 100% inspection. Presumably these items are important enough to justify such requirements.

Beyond the problem of Technical Order compliance, the reasons seem to be largely personal. Lack of understanding of the protection obtainable through statistical techniques and lack of knowledge of basic statistical principles is certainly one of the major reasons for resistance to the use of statistical quality control techniques. Current habits and practices are strongly entrenched and even knowledgeable supervisors have great difficulty in convincing inspectors and workmen that there is not something mystical or even dishonest about statistics.

Most large organizations, along with their rules and regulations, do not provide much incentive to motivate supervisors and inspectors to try new and improved methods. People realize that an outstanding contribution will bring little or no more recognition than a mediocre job. Lack of authority, the idea of self-protection, and simple "buck passing" make it difficult to initiate radically different systems.

It must be concluded that the Air Force will be unable to introduce statistical quality control concepts into the IRAN program on a broad scale

unless it can raise the capability of its maintenance quality control employees. Formal training programs, on-the-job training, supervised and carefully coordinated field service tests, publications introducing simple statistical concepts, and the provision of incentives for individual contributions are some of the steps the Air Force might take to reduce the personal resistance to change. Such an educational program will require years of continuing effort. It should, however, pay off in improved quality and lower cost of maintenance.